# Experimental and numerical investigation of effect of sawn timber dimensions in ultrasonic velocity measurements of Spanish softwoods

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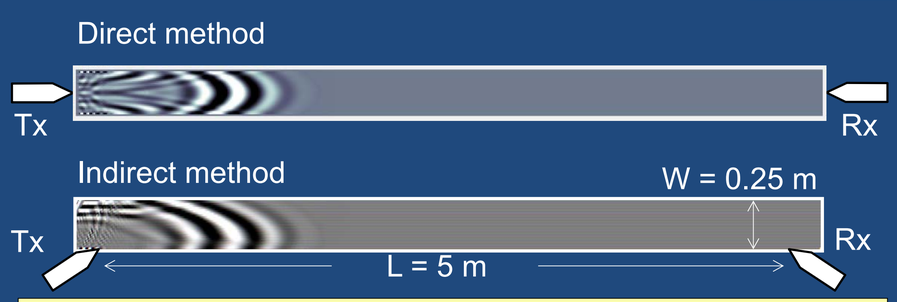
## INTRODUCTION

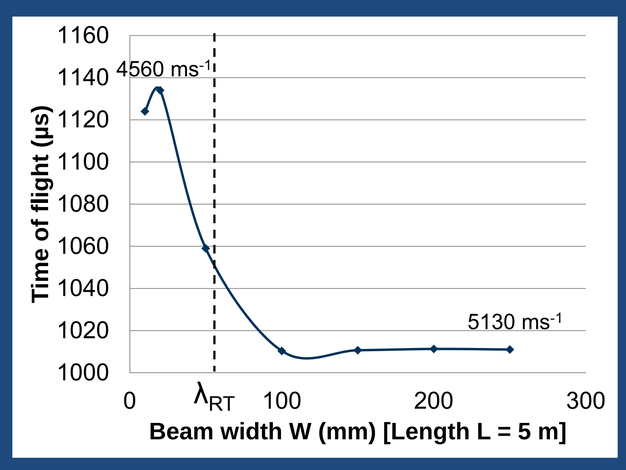
The effect of the dimensions of commonly tested Scots pine (*Pinus sylvestris* L.) timber and equipment testing frequency on ultrasonic velocity were investigated. A dedicated full-wave finite-difference time-domain software allowed simulation of pulse propagation through timbers of representative length and section combinations.

## NUMERICAL INVESTIGATIONS




Snapshots of 2D wave propagation in a typical softwood (*Picea abies* Karst.). Equipment: f = 22 kHz Sylvatest Duo.

Wavelength = Sound velocity / frequency [λ = c/f]
Grain: $\lambda_L$ = 230 mm, Cross-grain: $\lambda_{RT}$ = 61 mm




Direct method

| L (m) \ W (m) | 0.1 | 0.15 | 0.2 | 0.25 |
|---|---|---|---|---|
| 1 – 2 | 5120 | 5139 | 5137 | 5133 |
| 2 – 3 | 5148 | 5120 | 5135 | 5133 |
| 3 – 4 | 5145 | 5145 | 5131 | 5134 |
| 4 – 5 | 5144 | 5132 | 5116 | 5127 |

Indirect method

| L (m) \ W (m) | 0.1 | 0.15 | 0.2 | 0.25 |
|---|---|---|---|---|
| 1 – 2 | 5112 | 5146 | 5139 | 5127 |
| 2 – 3 | 5154 | 5105 | 5144 | 5138 |
| 3 – 4 | 5146 | 5144 | 5115 | 5147 |
| 4 – 5 | 5148 | 5152 | 5134 | 5122 |

Simulated sound velocities (m $s^{-1}$). Reference value for unbounded material is c = 5130 m $s^{-1}$. The largest variations are <0.5%.

## EXPERIMENTAL INVESTIGATIONS

The study was carried out in a specimen of 140x90x4000 $mm^3$ of *Pinus sylvestris* L. timber from Segovia (Spain). Sound velocity measurements $v_L$ were performed along the grain with direct (end to end) and indirect methods (same face) at 22 kHz and 45 kHz for grids of measurements points at specific distances. The measured sound velocities are comparable to the simulated values, thus similar dependencies on specimen dimensions are expected.

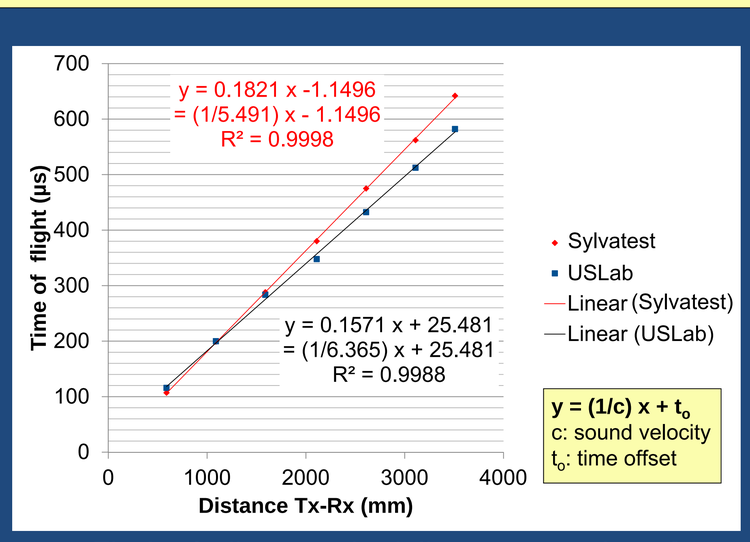



Fig A – Indirect method, linear regression of 7 measurements A-B; A-C; A-D; A-E; A-F; A-G; A-H

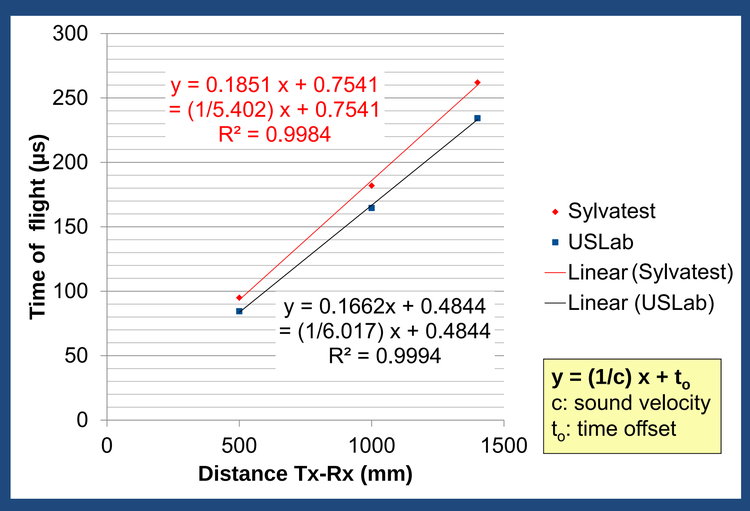
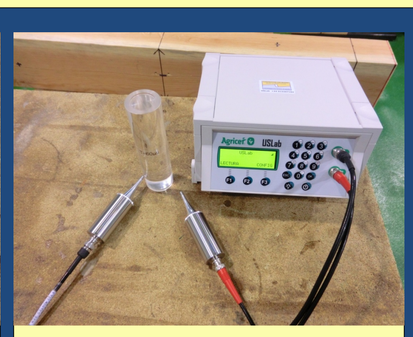



Fig E – Indirect method, linear regression of 3 measurements E-F; E-G; E-H

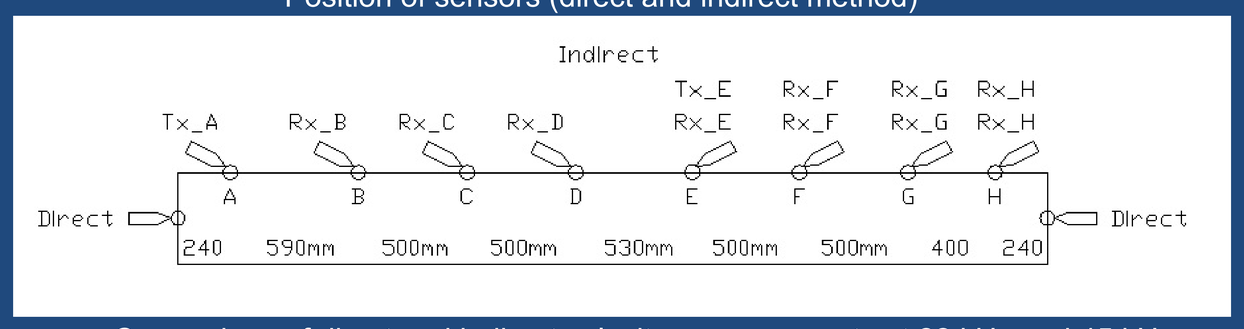
22 kHz Sylvatest Duo



45 kHz USLab

Ultrasonic indirect method

Position of sensors (direct and indirect method)




Comparison of direct and indirect velocity measurements at 22 kHz and 45 kHz

| | Sylvatest 22 kHz | USLab 45 kHz | Increment (%) |
|---|---|---|---|
| Direct velocity (m/s) | 5605 | 6104 | 9.0 % |
| Indirect velocity Fig A (m/s) | 5491 | 6365 | 15.6 % |
| Error direct – indirect Fig A | 2.1 % | 4.1 % | - |
| Indirect velocity Fig E (m/s) | 5402 | 6017 | 11.4 % |
| Error direct – indirect Fig E | 3.8 % | 1.5 % | - |

## CONCLUSIONS

- For sample sections larger than the cross-sectional wavelength $\lambda_{RT}$, the simulated sound velocity $v_L$ converges to $v_L = (C_L/\rho)^{0.5}$ (unbounded material). For smaller square sections the sound velocity drops down to $v_L = (E_L/\rho)^{0.5}$, where $C_L$, $E_L$ and ρ are the stiffness, elastic modulus and density in grain direction, respectively.
- The experiments confirm a linear regression between time of flight and measurement distance even at less than two wavelength <2$\lambda_L$ distance.
- Small differences (<4%) were observed between direct and indirect sound velocity measurements.
- The measured sound velocity values increased by 9-16% between the two tested frequencies. According to the simulations, this increase is not explained by the finite sample dimensions (maximum variation < 0.5%). It therefore appears to be an inherent characteristic of wood material. More experiments are required to confirm.

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